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A Brief Description of the Ljungström Method for Shale Oil Production

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A Brief Description of the Ljungström Method for Shale Oil Production.

Introduction.

The primary condition for oil production from shale is heating the shale to a high temperature, 700-1200 °F (different for different shales). Thereby the organic matter (kerogen) of the shale is converted (pyrolyzed) into oil, gas and residue (coke).

In the retorting methods the shale is mined, crushed and heated in a retort. There are, however, several shales, which are too deeply situated to be mined and processed economically, because of the high mining and transport costs. The in situ-method, invented and developed by Fr. Ljungström, consists in heating the shale deposit without moving it from its place in the rock.

Description.

The heat is applied through electrical heating elements, placed in vertical, drilled wells in the rock. The well pattern consists of regular quadrates or hexagons, covering the actual production area. The distance between the wells depends on the depth, the available electrical effect, the shale seam thickness and other factors.

The oil vapors and uncondensable gases are collected and transported through other vertical wells in the centres of the quadrates or hexagons.

Heat is not applied in the whole area simultaneously. Only a few rows of elements are heated and the heating zone moves slowly across the field. The length of the heating period depends on the ultimate temperature wanted, the electrical effect and the mass of rock to be heated by each element.

In order to avoid losses due to heat, oil and gas leakage through the surface, a certain top layer of the shale should be left unheated, unless there is a satisfactory tighting rock above the shale, which also serves as a heat insulation.

The applicability of the Lj-method.

The Lj-in situ-principle is not limited to oil shale. It may

also be used in oil production from oil sands, bituminous limestone and other materials. In oil shale the heat converts organic matter to oil, which leaves the shale as vapors, passing through the laminated rock to the collecting wells. In oil sands, however, the effect of the heat is not a pyrolysis but a heating of the free oil, causing a lowering of the viscosity and surface tension and thereby causing an increase in oil flow. Thus the oil leaves the rock as a liquid, flowing through the pores.

The applicability of the Lj-method varies depending on such material characteristics as oil yield, lamination, porosity, permeability, heat transfer data and specific heat. Moreover, seam thickness, height and tightness of overburden etc. are very important.

By the examination of the possibilities of applying the Lj-method to a certain shale (or sand) deposit the following steps are recommended:

1) Collection of data about the deposit, including such data as are mentioned above.

2) Laboratory tests on samples of the mineral giving information about the oil yield, porosity, permeability, heat transfer data etc.

3) As the Lj-method is very adaptable to varying conditions, it may be given a specific design in every case. It is, so to speak, not possible to copy an already built plant when designing a new plant. By this reason it is always recommended to make some field tests in order to collect experience and necessary base information before constructing the large scale plant. Not only the shale (oil sand) itself but also its surroundings in the field, the ground water and several other factors are of greatest importance for the function of the method. Such factors could be known only through field tests.

The most suitable scale for such a test depends of course upon the local conditions, the available money etc. The test should, however, be made as closely corresponding to a large scale plant as possible, with the exception that the electrical effect supplied per unit rock volume should be larger in the test in order to give more rapid results.

An example of a field test is given in a chapter below.

Equipment.

The electrical equipment needed [illegible] transformers cables, electrical heating elements [illegible] distributing station.

Further there is needed drilling machines, pumps, fans, washing towers, condensers, oil-water separators, tubings, storage tanks, steam plant etc.

Economy.

It is, of course, impossible to give an universal reply to the question of the actual production costs per barrel of oil. Too many factors are involved in the sum of costs. In order to make possible at least a rough estimation, however, an attempt to separate and compare the most important costs is made below.

The total production costs can be divided in the following parts:

1) Surface equipment, such as buildings, pipe-lines, condensers, tanks, further land costs. These costs are named A. Note. A more detailed analysis shows that A in its turn can be divided in terms, depending on the field area and on the production capacity of the plant.

2) Underground equipment [illegible] costs, including drilling, casings, tubings, elements, cables. If there are N wells per sq.ft. the field area is F sq.ft. and the cost per well is b, we obtain:

$$B = F.N[illegible]$$

3) Electrical energy for heating the rock. Assuming the seam thickness is d feet, the required energy is [illegible] kWh/cu.ft. and the energy price per kWh is e, this term will be:

$$C = F . d [illegible]$$

Strictly, the heat required for the pyrolysis (or vaporization) is n t proportional to the heated rock volume but to the produced oil (water). Laboratory tests have shown, however, that this percentage of the total electrical energy is relatively small and may be included in the above mentioned heat quantity.

4) <u>Administration, facilities, research and operating costs</u> = d.

Thus the total production costs amount [illegible]

Assuming an oil yield of p percent (by volume) of the heated rock, the price per barrel of produced oil will be:

$$E = \frac{100}{p} \cdot \frac{1}{F \cdot d} \cdot 5{,}62 \cdot (A+B+C+D)$$

(5,62 is the conversion factor from cu. ft. to barrels).

The Ljungström-plant at Kvarntorp, Sweden.

The following brief description of the Ljungström shale oil plant at Kvarntorp is given as an illustration of the principles, mentioned above. Because of the varying conditions from one shale deposit to another the figures below can not be used directly for extrapolation to other plants.

Field tests.

After thorough laboratory experiments by the inventor, Dr. Fredrik Ljungström, some field tests were made that were intended to give an answer to the question of the applicability of the method to actual Swedish shale deposits.

At the shale deposit at Kvarntorp in middle Sweden a little field was selected, where the first field tests were made. The first test consisted of six wells arranged in a hexagon pattern around a single oil vapour outlet well in the middle (Fig. 1), drilled to a depth of about 10 feet in the shale seam. Alrdady this first test gave valuable hints about the most suitable element-constructions, specific electrical effects (pro length unit of the elements), corrosion problems etc.

In the second test the wells were about 30 feet deep. New element materials and element types were tested and new experiences were made concerning the gas- and oil-collection and condensing.

The following three tests were arranged to give detailed information about the energy required for complete oil recovery and about the temperature conditions at different times and different distances from the element and varying heating effects. The results obtained were used for a detailed mathematical examination of the optimum element pattern, heating effect and length of heating period.

Finally a sixth field test was made on a somewhat larger scale. In a field about 45 x 50 feet one hundred element wells (diameter ~ 21/4") were drilled in a hexagonal pattern with a well spacing of 4,2 feet. Elements, cables, tubings, condensers etc. were d signed for a full scale plant and a scheme for successive energy supply was prepared. This field test lasted two years and produced totally about 500 barrels of oil.

Full-scale plants.

Through the above mentioned tests the in-situ-principle had proved to be suited for its purpose and the main practical problems were solved. It was found that special attention must be paid to the choice of element material with regard to the thermal and possible chemical strains that might appear. The electrical effect must be balanced between the advantages of rapid heating of the rock and the disadvantages of high element temperature.

Further the importance of a tightly covering cap rock over the pyrolyzed shale seam was observed.

As the main difficulties were overcome, however, there was decided to build a semi-full-scale plant, which was started in 1943. It was designed for an energy supply of 3700 kW and it produced about 3 barrels/hour. At this plant the most economic drilling methods, element-isolation, design of collecting tube system etc. were studied. Analysis were made on oil and gas and the best utilization and refining of the products were studied.

In 1944 finally a full-scale plant was designed and built at Norrtorp. The effect amounted to 20.000 kW and the oil yield reached the full production of about 18-20 barrels/hour or 150.000 barrels/year. The earlier experiences were confirmed and no essential unforeseen difficulties appeared.

The actual shape of the LJ-plant at Norrtorp is shown on figures 1-5.

Economy.

The results obtained at the Norrtorp plant have been studied from the economical point of view. A comparison between the terms A, B, C and D in the cost formula (page 4) shows that under the conditions present in this plant, the energy costs amount to about 50 percent of the total costs. This percentage varies with the price of the obtainable electrical energy and shows the important rôle of this price in the oil price.

Another important factor is the field area. Round the heated field there are some losses in heat, but also in oil and gas (through leakage and condensation in the neighbouring parts of the shale). The larger the whole field, the smaller are these losses per volume of produced oil.

Finally, the economy of the plant is also depending on the effect, supplied per unit field area. The lower the effect, the longer the heating period and in proportion thereto, the larger the heat losses.

Kvarntorp, June 29th, 1949.

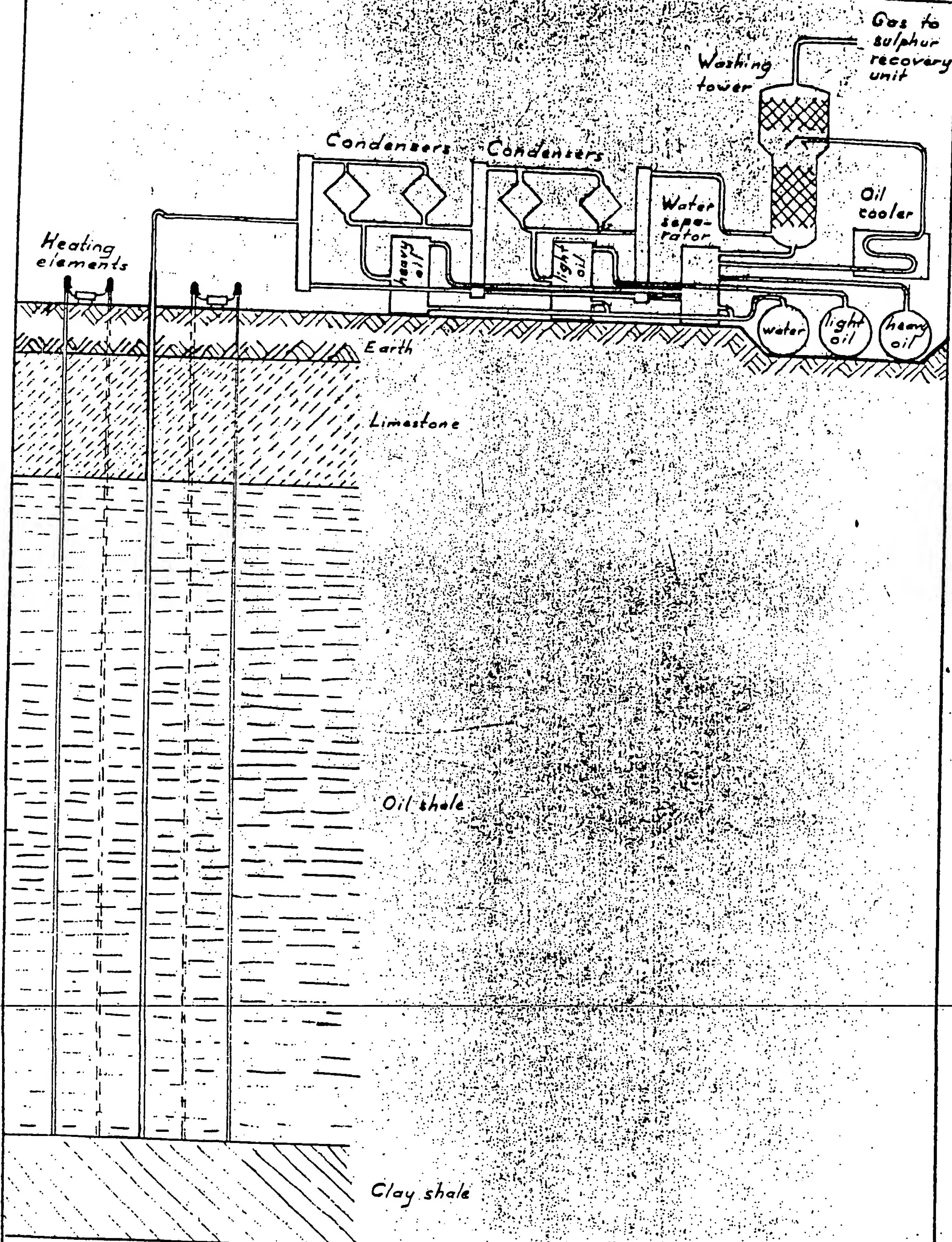
Gösta Salomonsson

SVENSKA SKIFFEROLJE A.-B.
Ljungströmsanläggningen

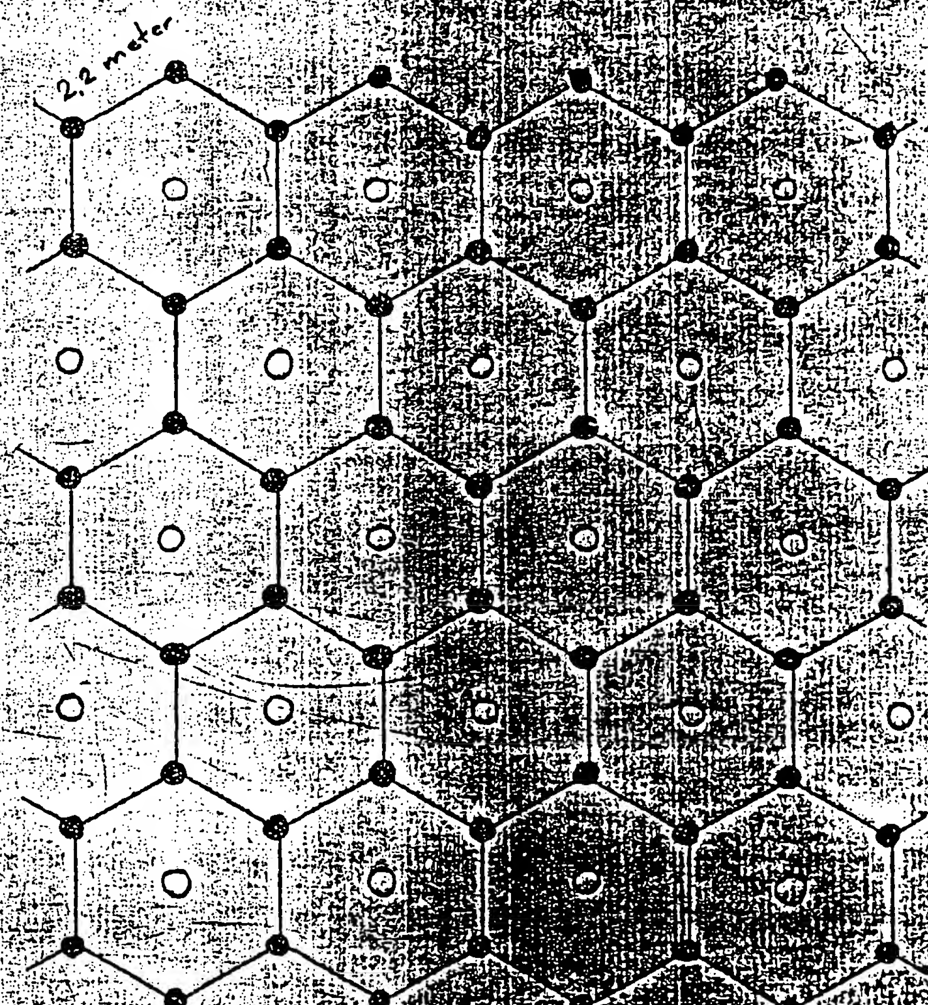
The Ljungström System for shale oil recovery.

Bl. Page 8.

Reg.-nr. Lj-



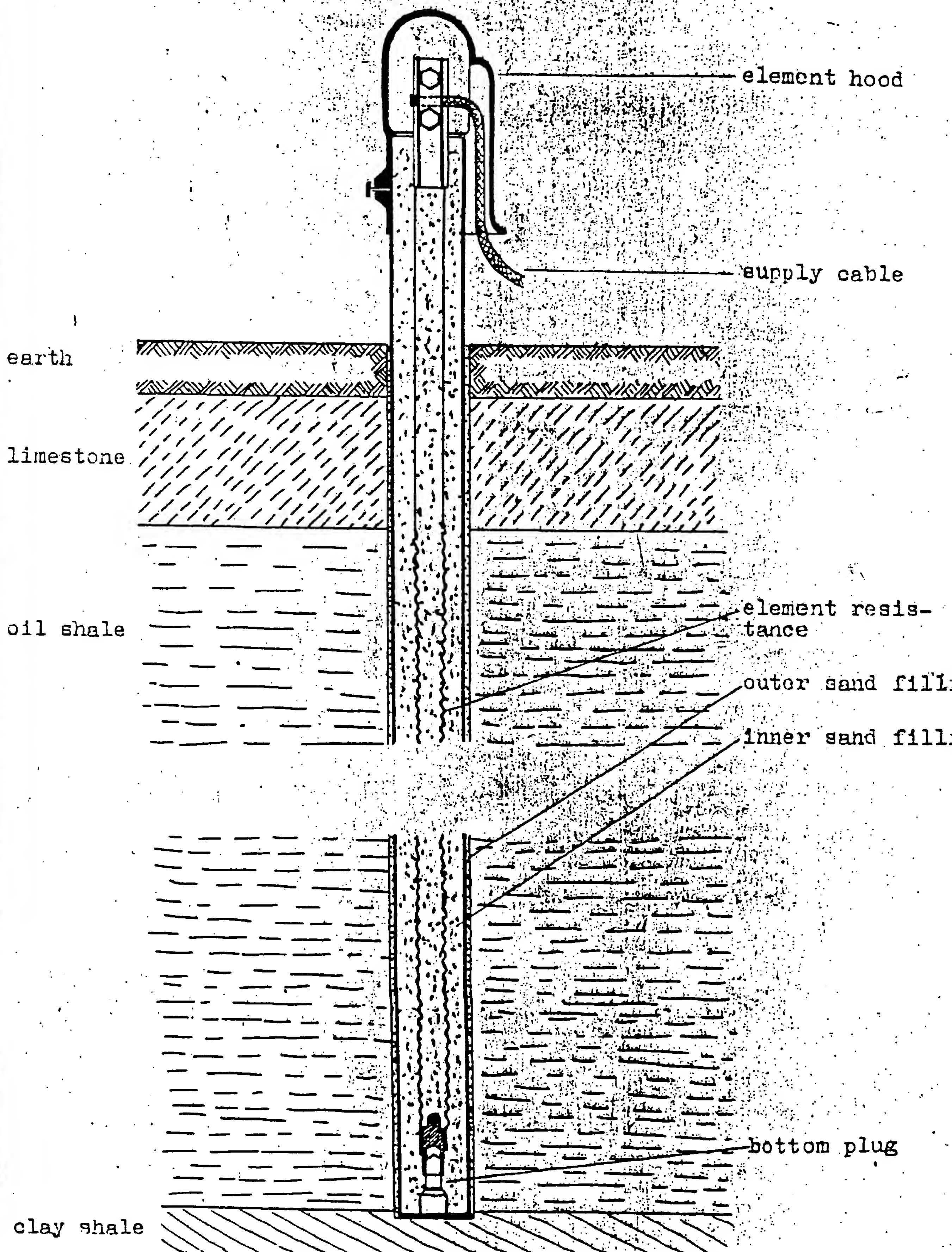
Part of a Lj-field, covered with
regular hexagones.



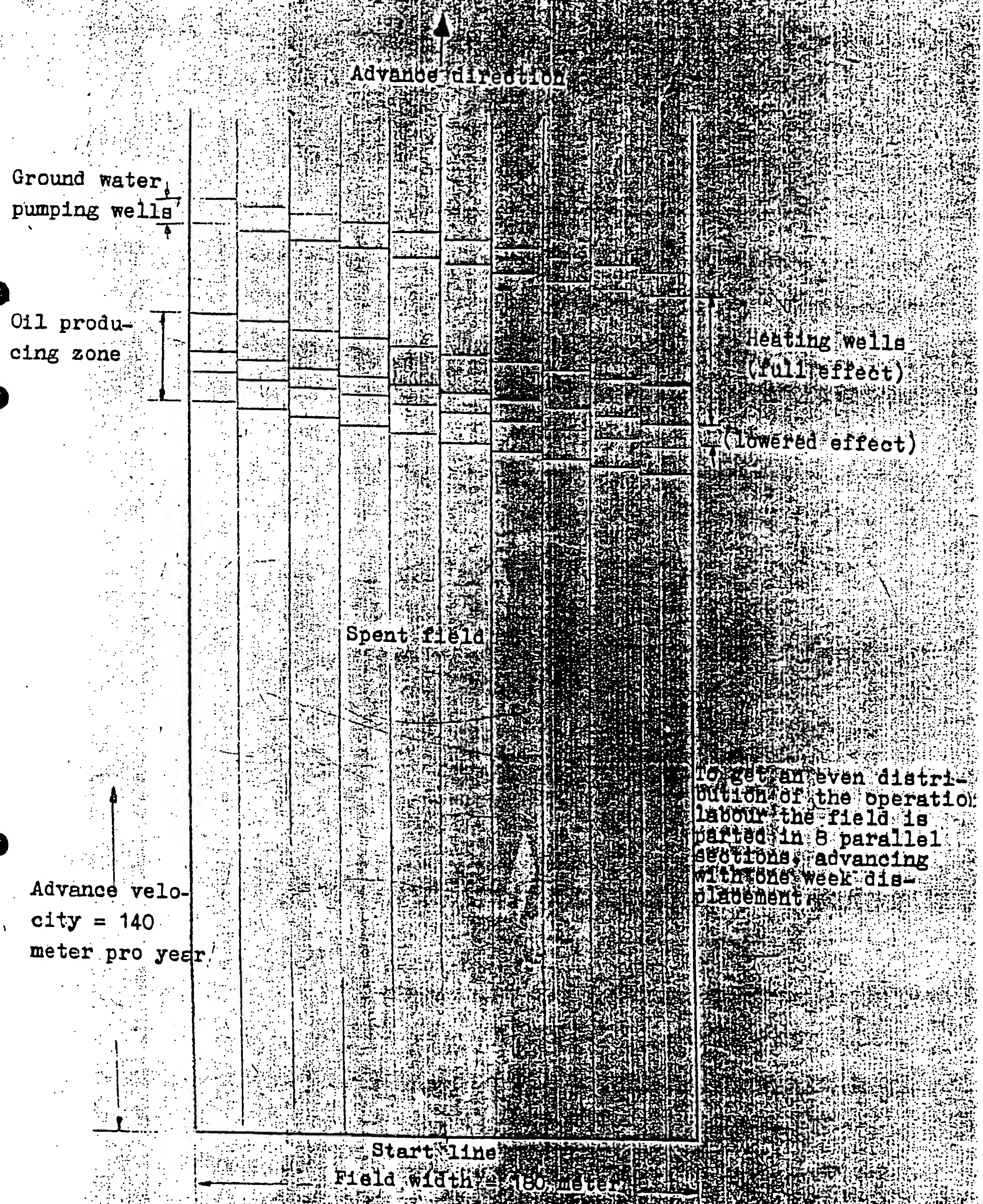
● = heating element

○ = oil outlet well

SVENSKA SKIFFEROLJE A.-B. Ljungströmsanläggningen	Section through a heating element at the Norrtorp plant.	Bl. Page 10. Reg.-nr. Lj-



Scheme for working up a shale fi ld by the Ljungstrom method.



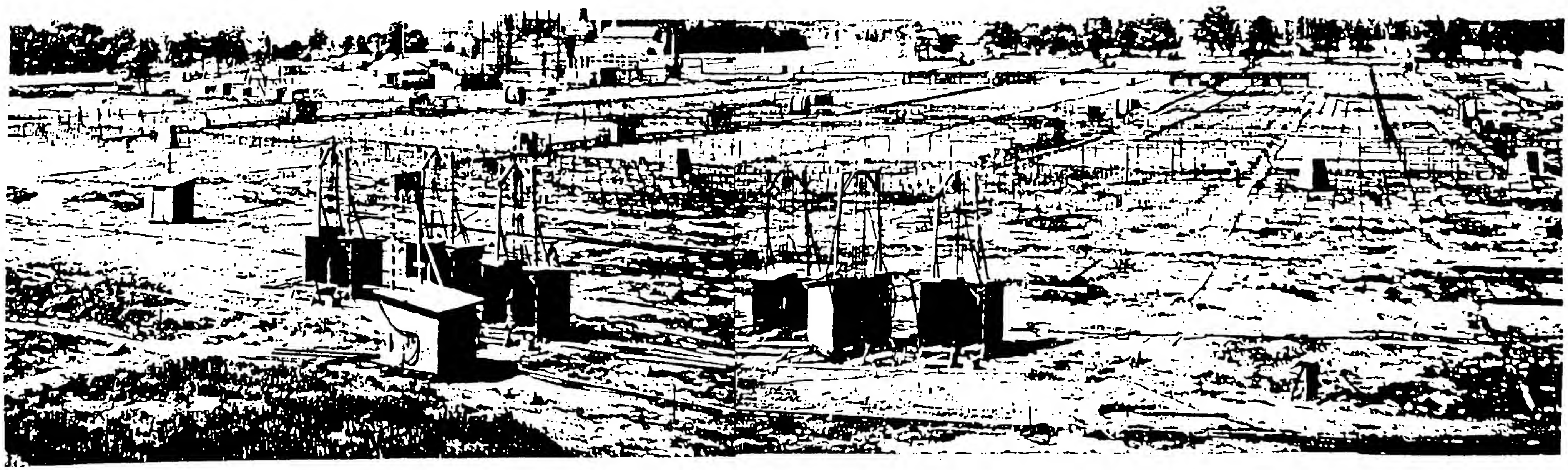


Fig. 5. View of the Norrtorp plant.